MEGI

MESTRADO
Estatística e Gestão de Informação
Master in Statistics and Information Management

GREEN IT ADOPTION VIA VIRTUALIZATION

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Dissertação apresentada como requisito parcial para obtenção do grau de Mestre em Estatística e Gestão de Informação

Dissertation presented as partial requirement for obtaining the Master's degree in Statistics and Information Management

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Novembro 2012

ACKNOWLEDGEMENTS

I would like to present my gratitude to my Ph.D. supervisor, Dr. Tiago Oliveira, for providing the subject of this dissertation and also by his enthusiasm, inspiration and never-ending availability. Throughout my thesis-writing period, he provided great support, encouragement, sound advice, good teaching and lots of good ideas.

I would like to thank to Manoj Thomas, Ph.D., for his insights, opinions, encouragement and availability.

I would like to thank to my colleague Helena Miranda by her companionship and dedication during the first year of master as well as her moral support during the thesis-writing period.

I would like to thank to my sister Andreia and my partner Sérgio for their support, patient and motivation.

Finally, I would also like to thank all the companies who have contributed to this dissertation.

ABSTRACT

This study attempts to test and validate the theoretical framework proposed by Bose and Luo (2011) that identifies and examines the factors that contribute to the assessment of a firm's readiness to go green via IT-enable virtualization. The conceptual framework is based on three theoretical foundations: (1) technology-organization-environment (TOE) framework; (2) process virtualization theory (PVT); and (3) diffusion of innovation (DOI) theory. To test the framework, data were collected from 251 firms in Portugal and partial least square (PLS) was used to estimate the research model. The study found that environmental context (i.e., competition intensity and regulatory support) influences Green IT adoption more than the technological and organizational contexts. The research also confirmed that the pre-stage of adoption (i.e., Green IT initialization) influences the formal stage of adoption (i.e., Green IT integration), which in turn influences the post-adoption stage (i.e., Green IT maturation). As sustainable products and practices become increasingly relevant, the study adds new knowledge to this emergent area of IS research and provides valuable insights to IS managers and decision makers.

KEYWORDS

Green IT; virtualization; process virtualization; Green IT framework; technology-organization-environment (TOE); process virtualization theory (PVT); diffusion of innovation (DOI)

RESUMO

Este estudo pretende testar e validar o modelo teórico proposto por Bose e Luo (2011), o qual identifica e analisa os factores que contribuem para a avaliação por parte das empresas da sua capacidade de adoptar tecnologias de informação sustentáveis (Green IT) através da virtualização. O modelo copceptual é baseado em três fundamentos teóricos: (1) contexto de inovação tecnológica (TOE framework), (2) teoria do processo de virtualização (PVT theory) e (3) difusão da inovação (DOI). Para testar o modelo, foram recolhidos dados de 251 empresas que operam em Portugal e posteriormente estimado o modelo através da metodologia de mínimos quadrados parciais (PLS). Através do estudo concluiu-se que contexto externo à empresa (ou seja, a intensidade da concorrência e o apoio regulatório) influencia mais a adopção de TI sustentáveis que os contextos tecnológico e organizacional. O estudo também confirmou que a fase de pré-adopção (i.e., inicialização de TI sustentáveis) influencia a fase formal de adopção (ou seja, a integração de TI sustentáveis), que por sua vez influencia a fase de pós-adopção (i.e., maturação de TI sustentáveis). Com os produtos e as práticas sustentáveis a tornarem-se cada vez mais relevantes, este estudo acrescenta novos conhecimentos a esta área emergente de Sistemas de Informação e fornece informações valiosas tanto para gestores de sistemas de informação como para decisores (e.g., politicos, empresariais, etc.).

PALAVRAS-CHAVE

TI sustentáveis; virtualização; virtualização de processos; modelo TI sustentáveis; contexto da inovação tecnológica; teoria da virtualização de processos; difusão de inovação

SUBMISSON

Submission resulting from this dissertation:

Paper

Green IT adoption via virtualization. (CEGI list - level 2) (Submitted)

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ABBREVIATIONS

IT	Information Technology
IS	Information Systems
Green IT	Green Information Technology
TOE	Technological-Organizational-Environmental framework
PVT	Process Virtualization Theory
DOI	Diffusion of Innovation
K-S	Kolmogorov-Smirnov
SEM	Structured Equation Modeling
PLS	Partial Least Square
AVE	Average Variance Extracted
R^2	R-square

1. INTRODUCTION

With a growing consumer preference towards products and services that align with social and environmental benefits, there is a heightened drive among businesses to adopt sustainability initiatives as an important strategic directive. IT assets (hardware platforms and network components, software applications, and hosting environments) are a major source of carbon emission and energy consumption, as a result of which sustainability initiatives pursue making information systems “green” (Murugesan, 2008; Sang-Hyun et al., 2012). Green IT (information technology) is the use of IT resources in an energy-efficient and cost-effective manner (Bose and Luo, 2011).

Companies recognize that Green IT offer value added returns on investment via cost cutting, reduced risk, increased revenues and brand value (Esty and Winston, 2006). Building environmental thinking into the business strategy is not only fiscally compelling, but also ensures social responsibility and compliance with environmental regulations. According to Lamb (2009), consolidating IT operations, and using virtualization to reduce the server footprint and energy use are two of the most well-recognized and widely implemented Green IT initiative in the past few years.

Bose and Luo (2011) proposed a theoretical framework to assess the factors that contribute to a firm’s readiness to go green via IT-enabled virtualization. Their model combined three well recognized IS theories namely - (a) technology-organization-environment (TOE) framework, (b) process virtualization theory (PVT) and (c) diffusion of innovation (DOI). In their conceptual model, the innovation decision (i.e., a firm’s readiness to implement Green IT initiatives) is assessed using an integrated TOE and PVT analysis, and the stages of implementation are guided by the DOI analysis. Although the study is a significant step towards understanding Green IT adoption via virtualization process, the research falls short in empirically validating the conceptual framework. The purpose of this research is to fill this gap by methodologically testing the theoretical framework proposed by Bose and Luo (2011).

The rest of this paper is organized as follows. In the next section, we provide an overview of Green IT and describe the theoretical foundations of the model. The conceptual model and the hypotheses are presented in section 3. The research method is discussed in Section 4 and the results are analyzed in section 5. Section 6 discusses the major findings of the study, theoretical contributions, and managerial implications. Finally, we conclude the paper by summarizing the limitations of the study and suggesting directions of future research.

2. BACKGROUND

2.1. GREEN IT

The research field of Green IT has been conceptualized in several ways, with different scopes, and with a wide variety of terminologies and concepts (Dedrick, 2010). Consequently, there is a lack of universal understanding of Green IT (Velte et al., 2008). According to Capra and Merlo (2009), Green IT refers to three distinctive areas: (1) energy efficiency of IT, (2) eco-compatible management of the lifecycle of IT, and (3) IT as an enabler of green governance. Murugesan (2008) define Green IT as the focus on designing, manufacturing, using and disposing of computer, servers and associated subsystems efficiently and effectively with minimal or no impact on the environment. The main goals of Green IT can be summarized as follows. It enables energy and material savings, and simultaneous improvement in organizational efficiency (for e.g. the replacement of physical hardware by virtual products free up valuable floor space in data center and reduces IT maintenance activities and costs) (Loos et al., 2011). Green IT minimizes environmental impact (for e.g., the introduction of the smart grid to increase the share of renewable energy costs and reduce the overall carbon footprint) (Sang-Hyun et al., 2012). It helps organization be more competitive and sustain its competitive advantage through branding and image creation (Esty and Winston, 2006; Velte et al., 2008; Watson et al., 2010). Molla et al. (2009) summarizes the inhibitors to Green IT adoption. They include cost of Green IT solution, unclear business value of greening IT, lack of government incentives and business leadership, inadequate skills and IT sophistication, extent of mimetic pressure, and the absence of government regulations.

Virtualization can be defined as the application of flexible, network-enabled (Applegate et al., 2003) information technology to provide efficiency in infrastructure operation (Armbrust et al., 2010; Thomas et al., 2009), automation of business processes, and organizational resource utilization (Bose and Luo, 2011; Venkatraman and Henderson, 1998). Virtualization allows the consolidation of resources leading to improvements in IT operations by lowering the expenses, reducing data center footprints, and curtailing greenhouse emissions. Benefits of virtualization also include simplified maintenance procedures, improved disaster recovery plans, and the ability to provision IT systems and processes more quickly. The value added from social, economical, and ecological sustainability benefits has resulted in virtualization emerging as an important driver to Green IT adoption (Bose and Luo, 2011; Harris, 2008).

As with any other technological implementation, Green IT implementation is a process that passes through different stages of adoption once its benefits to the business model is recognized. Bose and Luo (2011) assess the innovation capability of a firm to implement Green IT via virtualization using a three-stage process. Stage I - *Green IT initialization* is the pre-adoption stage where the organization starts evaluating the adoption of Green IT practices in its value chain activities. Stage II – *Green IT integration* is the effective adoption of the practices as a strategic consolidation. And finally, Stage III – *Green IT maturation* is the post-adoption stage where the practices are routinized as part of the value chain activities.

2.2. THEORETICAL FOUNDATION

The integrative research model proposed by Bose and Luo (2011) combines the process-virtualization-theory and the TOE theoretical framework to assess the organization's potential to undertake Green IT initiatives and the stages of Green IT implementation. It uses the diffusion of innovation theory to capture the salient factors from an organizational, technological and environmental perspective. The following sections briefly summarizes each of the three established IS theories.

2.2.1. Technology-organization-environment (TOE) framework

Tornatzky and Fleischer (1990) proposed the TOE framework to explain the organization's adoption of technological innovation. The framework considers three contexts that influence the adoption of innovation - technological context, organizational context and environmental context. The technological context refers to the existing technologies that are in use by the organization (internal) and new technologies that are available for adoption (external). The organizational context refers to the descriptive characteristics of the firm (firm size, managerial structure, degree of centralization), available resources (human resources and slack resources), and the process of communication (formal and informal) among the employees. The environmental context refers to the external elements that influence the organization to adopt new technologies (for e.g., market elements, competitors, and government regulations).

The TOE framework has been used in several studies to understand the adoption of a new technology, such as Green IT (Bose and Luo, 2011), Electronic Data Interchange (EDI) (Kuan and Chau, 2001), open systems (Chau and Tam, 1997), e-business (Lin and Lin, 2008; Oliveira and Martins, 2010; Zhu et al., 2003; Zhu and Kraemer, 2005; Zhu et al., 2006b) and e-commerce (Liu et al., 2008).

2.2.2. Process virtualization theory (PVT)

The PVT (Overby, 2008) is based on the premise that some processes are more amenable to being conducted virtually than others. It describes how amenable the process is to conduct without physical interaction between people or between people and objects. The dependent variable of this framework, process virtualization, is explained using four independent variables: (1) *sensory requirements* of the process participant to enjoy a full sensory experience, which includes the five senses – taste, see, hear, smell, touch, (2) *relationship requirements* of the process participant to interact with others, (3) *synchronism requirements*, the degree to which the process activities can take place with minimal delay, and (4) *identification and control requirements*, the degree to which the process provides unique identification of the process participants and the ability to control or influence their behavior. The theory suggests that all four requirements have a negative influence on the dependent variable (i.e. process virtualization). However, three IT-enabled moderating constructs positively influence the process virtualizability. They are: (1) the representation capability of IT to present audio, video, haptic, and olfactory facilities, (2) reach, which is IT's capability to allow participation across time and space, and (3) monitoring capability, which is the capability of IT to authenticate process participants and track activities. Within the technological context of the organization, Bose and Luo (2011) posit that sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness will positively influence Green IT initialization.

The PVT has been used in several research settings. They include understanding the shift from physical to electronic trading processes in Wholesale Automotive Market (Overby, 2008), telecommunication sector (Czarnecki et al., 2010), and cross-channel instant messaging (Li et al., 2009).

2.2.3. Diffusion of innovation (DOI) theory

DOI (Rogers, 2003) is a prominent adoption model used in Information Systems (IS) research (Alam, 2009; Azadegan and Teich, 2010; Dedrick and West, 2003; Ifinedo, 2011; Leinbach, 2008; Zhu et al., 2006a). It proposes four elements that influence the spread of a new idea: innovation, communication channels, time, and a social system. The assimilation of an innovation passes through different stages of adoption (Rogers, 2003). They are (1) knowledge – advancing awareness of an innovation and some idea of how it functions; (2) persuasion – developing a favorable or unfavorable attitude toward the innovation (3) decision – engaging in activities that lead to a choice to adopt or reject the innovation (4) implementation – employing the innovation and evaluating its usefulness, and (5) confirmation – finalizing the innovation-decision already made. In the conceptual framework proposed by Bose and Luo (2011), the stages of Green IT adoption are guided by the DOI analysis. The stages 1, 2, and 3 are incorporated at Green IT initialization (i.e., pre-adoption) where firms make the initial assessment of Green IT. Stage 4 is part of the Green IT integration (i.e., formal adoption) and stage 5 is Green IT maturation (i.e., post-adoption) where the greening of IT is integrated in the firm's value chain activities.

DOI has been used in several application areas, such as intranet (Eder and Igbaria, 2001), web development (Beatty et al., 2001), enterprise resource planning (ERP)(Bradford and Florin, 2003; Ruivo et al., 2012), e-procurement (Li, 2008), e-business (Hsu et al., 2006; Zhu et al., 2006b), and radio frequency identification (Wang et al., 2010).

3. CONCEPTUAL MODEL AND HYPOTHESIS

3.1. THE CONCEPTUAL MODEL

In accordance to the integrative theoretical model proposed by Bose and Luo (2011), we establish the following research question: what factors guide the adoption of Green IT via virtualization? Thus, the objective of this research is to assess the readiness of an organization to adopt Green IT practices through virtualization and the stages of Green IT implementation. It aims to empirically validate the nine untested propositions hypothesized by Bose and Luo (2011). The conceptual model grounded in the three IS theories described above (TOE, PVT, and DOI) is shown in Figure 3.1. The TOE framework to posit that the organizational adoption and implementation of Green IT is influenced by the technological, organizational and environmental contexts. The constructs of PVT theory are incorporated in the Technological Context of TOE framework to assess the virtualization of the Green IT initiatives. The stages of Green IT implementation are supported by DOI theory.

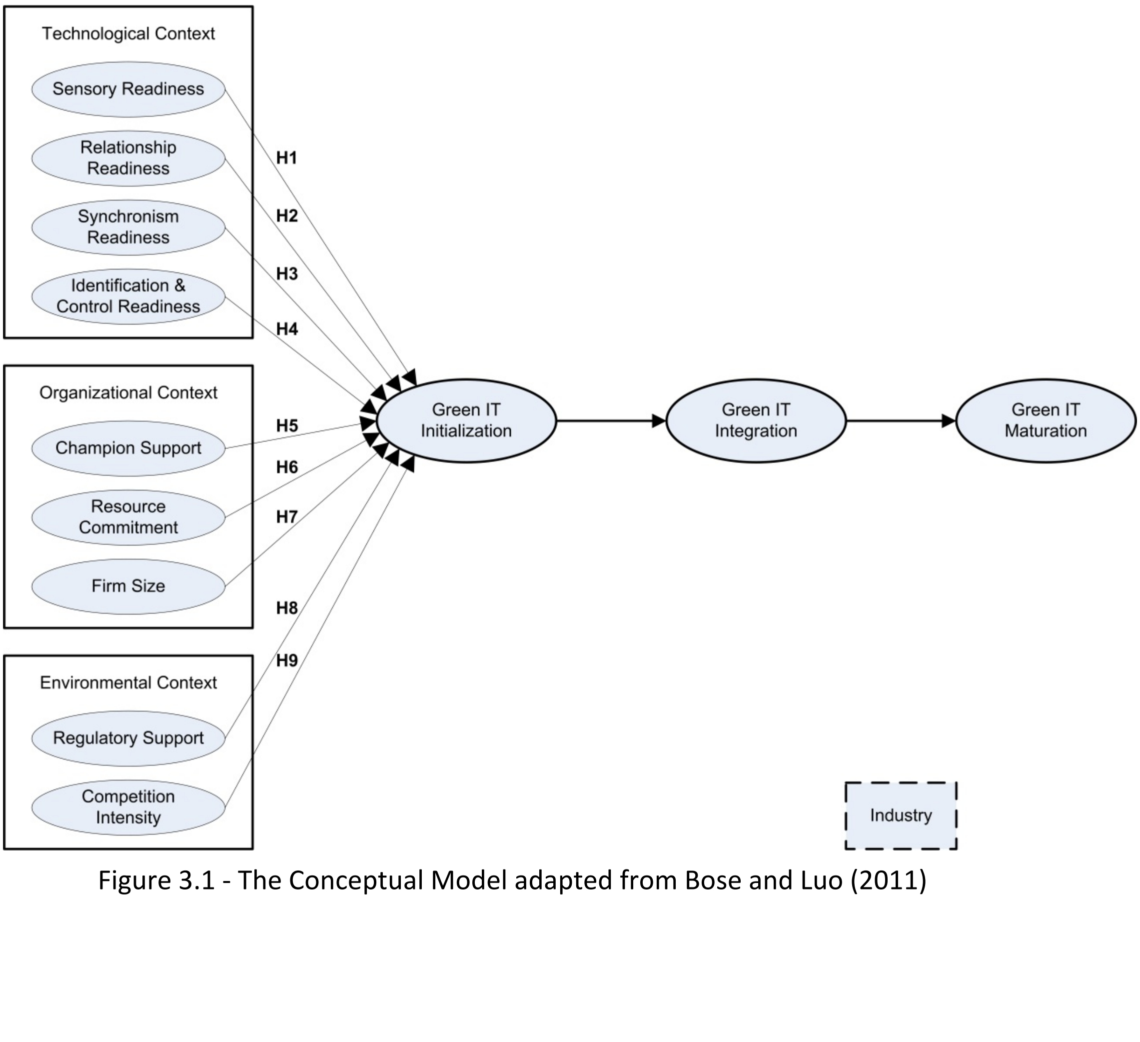

Figure 3.1 - The Conceptual Model adapted from Bose and Luo (2011)

3.2. Hypothesis

3.2.1. Technological context

H1. *Sensory readiness will positively influence Green IT initialization.*

In the initialization phase of Green IT, sensory readiness is the degree to which the virtualization process enables participants to experience the sensory elements of the physical world (Overby, 2008). Virtualizability of business processes and IT operations facilitate a wide range of sensory functions for the process participants (for e.g., online shoppers use 3D visual interfaces to comprehend finer details of clothing or footwear, growth in popularity of vocal interfaces for information search and retrieval, audio-visual support in distance learning environments). Thus the sensory readiness of virtualizability will positively influence Green IT initialization by enabling the participants to enjoy the sensory experience of the process and the other process participants or object (Bose and Luo, 2011; Overby, 2008).

H2. *Relationship readiness will positively influence Green IT initialization.*

Relationship readiness refers to the need for process participants to interact with one another in a professional context (Bose and Luo, 2011). It is possible to establish relationship requirements to conduct a process through virtualization (Overby, 2008). Interaction capabilities and media richness provided by virtual environments (via email, instant messaging, video chat, and social networking sites) can provide cues (gestures, postures, attentiveness, etc.) similar to those conveyed through face-to-face interactions (Bose and Luo, 2011; Hitsch et al., 2010). Hence, relationship readiness will positively influence Green IT initiatives.

H3. *Synchronism readiness will positively influence Green IT initialization.*

Synchronism readiness is the degree to which the activities in a process need to occur quickly with minimum delay (Bose and Luo, 2011). Physical processes tend to be inherently synchronous as process participants interact with one another with little delay (Overby, 2008). Process and infrastructure virtualization (for e.g. instant messaging, video conferencing or VoIP) enable parties to establish synchronous communication virtually. These technologies allow interaction between participants and process objects on a real-time basis with minimal delay, even when the participants in the process are geographically dispersed. Thus, synchronism readiness will positively influence Green IT initialization.

H4. *Identification and control readiness will positively influence Green IT initialization.*

Identification and control readiness refers to the degree which the process requires unique identification of process participants and the ability to exert control over their behavior (Overby, 2008). In an organizational setting, it is unlikely that the participants remain anonymous when establishing process relationships. Although virtualizability makes it easier for participants to hide their identity, technological advancements in the field of identification management (for e.g., biometrics, and profile management) and authentication control (for e.g., password verification and directory services) makes it possible to accurately identify the process participants. Furthermore, it is also possible to control and monitor the activities done virtually (Bose and Luo, 2011). Hence, identification and control readiness will positively influence Green IT initialization.

3.2.2. Organizational context

H5. *Organizations with greater champion support are more likely to initiate Green IT.*

Top management's commitment and support is crucial to the success of a project (Lacity et al., 2009; Lacity and Willcocks, 1998). Top management commitment is required to promote the acceptance and adoption of a new technology, and to help overcome the challenges of the implementation (Beath, 1991; Crum and Premkumar, 1996; Zhu et al., 2006b). The support of a champion at the top management level (for instance, the CEO) who recognizes the benefits of Green IT initiatives to the organization (Meyer, 2000) can provide the necessary drive to influence the adoption of virtualization. Prior studies have shown that champion support is a crucial factor between adopters and non-adopters for emerging business and technological processes (Grover and Goslar, 1993; Teo and Ranganathan, 2004). Thus, Bose and Luo (2011) states that the implementation of Green IT initiatives requires support from the organization's top management.

H6. *Organizations with greater resource commitment are more likely to initiate Green IT*.

The commitment of the organization to adopt an innovation is reflected by their financial commitment to implement that innovation (Zhu and Kraemer, 2005).

Availability of resources is an important antecedent to IS diffusion (Iacovou et al., 1995; Low et al., 2011; Ramamurthy et al., 1999; Zhu and Kraemer, 2005). As the implementation of Green IT requires financial investment in hardware, software, and workforce, Bose and Luo (2011) posit that it will be easier for organizations with greater resource commitment to adopt Green IT initiatives.

H7. *Organizations in large size are more likely to initiate Green IT.*

For this analysis, Bose and Luo (2011) define firm size based on the number of employees in the organization. It is one of the most studied organizational factors in the innovation and adoption literature (Bose and Luo, 2011; Lee and Xia, 2006; Oliveira and Martins, 2010). According to Rogers (1995) and Damanpour (1996), large-size firms (those with more than 500 employees) facilitate the innovation initiation and adoption since they tend to have more resource advantages than smaller firms. The implementation of Green IT initiatives requires qualified and skilled human resources in technological, managerial and financial units. Hence, large organizations are more likely to have the workforce or allocate resources required to implement the innovation (Bose and Luo, 2011; Zhu et al., 2006b).

3.2.3. Environmental context

H8. *Organizations with greater regulatory support are more likely to initiate Green IT.*

Regulatory support refers to the support given by the government authority in order to encourage IT innovation by firms (Zhu et al., 2006b). The impact of existing laws and regulations can be critical in the adoption of new technologies (Zhu et al., 2003; Zhu and Kraemer, 2005; Zhu et al., 2006b). Government regulations related to business processes (e.g., Telework Enhancement Act), innovation diffusion (e.g. Carbon Reduction Commitment Energy Efficiency Scheme) and environmental impacts (e.g., National Computer Recycling Act) can influence the Green IT initiatives in an organization (Dasgupta et al., 1999; Umanath and Campbell, 1994). Regulatory incentives such as tax relief, and monetary support for implementing Green IT can help organizations achieve their sustainability goals (Bose and Luo, 2011). Thus, organizations with regulatory support are more likely to initiate Green IT.

H9. *Organizations facing higher competition intensity are more likely to initiate Green IT*.

Competitive pressure has long been recognized in the innovation diffusion literature as an important driver for technology diffusion (Al-Qirim, 2007; Battisti et al., 2007; Iacovou et al., 1995; Lai et al., 2007; Zhu et al., 2003). It refers to the pressure felt by the firm from competitors within the industry (Low et al., 2011; Oliveira and Martins, 2010; Zhu et al., 2003). In a competitive market environment, building environmental thinking into the business is a strategic necessity for image creation and brand recognition. Green IT through virtualization helps sustain competitive position, offer benefit of greater operational efficiency, and provide better market visibility. Hence, the degree of competition within the industry influences the adoption of Green IT (Bose and Luo, 2011).

Controls

We used industry to control data variation not explained by the other variables. As suggested in IS literature, we incorporated industry dummy variables as control variable (Bresnahan et al., 2002; Chatterjee et al., 2002; Oliveira and Martins, 2010; Soares-Aguiar and Palma-dos-Reis, 2008; Zhu et al., 2006a; Zhu et al., 2003).

4. METHOD

4.1. MEASUREMENT

To test the model presented in Figure 3.1 we conducted a survey of organizations in Portugal. Following Moore and Benbasat (1991) and by taking into consideration the recommendations by Bose and Luo (2011), a survey instrument was developed from existing literature by choosing appropriate items and creating items as necessary. Since the questionnaire was administered in Portugal, the English version was translated into Portuguese. A group of five established academic IS researchers and two language experts reviewed the instrument for content validity (Brislin, 1970; Venkatesh et al., 2012). The measurement instrument was then tested among a small sample (pilot study with 30 firms) that was not included in the main survey. The objective was to examine whether the respondents have difficulty answering the questionnaire, as well as test the reliability and validity of the scales. Some items were dropped to reduce the instrument length and others were slightly modified to reduce ambiguity and simplify interpretation. The results of the pilot study provided preliminary evidence of the reliability and validity of the scales.

The resulting survey instrument and measurement items used in this analysis are shown in Appendix. The dependent variable *Green IT Initialization* was measured based on how the firms rated the potential benefits of Green IT before the adoption of virtualization technology. Following the recommendation of Bose and Luo (2011), four items were used to measure this construct: increase productivity, market expansion, entering new businesses, and supply chain coordination (Liu et al., 2008; Zhu et al., 2006b). *Green IT Integration* was measured using the approach of Zhu et al. (2006b) to determine technology diffusion in organizations. As per the suggestion of Bose and Luo [2011], the firm's use of green IT initiatives in the value chain activities (for example, marketing, sales, after-sales services, and inbound and outbound logistics management) was aggregated to form the dependent variable. *Green IT Maturation* was measured by the extent of virtualization–driven Green IT initiatives to support value chain activities (Zhu et al., 2006b). Three items were measured: percent of total sales, total services and total procurement conducted through IT initiatives (Bose and Luo, 2011).

The independent variable *Sensory Readiness* was measured by two items indicating the importance of sensory experience in a virtual environment (Overby and Konsynski, 2008). *Relationship Readiness* was measured by two items adapted from

Overby and Konsynski (2008) reflecting the importance of relationship between parties in a virtual process. *Synchronism Readiness* was measured by two items denoting the need to complete transaction tasks quickly (Overby and Konsynski, 2008). *Identification and Control Readiness* was measured by two self-developed items in accordance with Bose and Luo (2011) indicating the importance of identifying the participants. *Champion Support* was measured by three self-developed items based on Bose and Luo (2011) to determine the importance of top management support in Green IT initiatives. *Resource Commitment* represents the financial resources dedicated to Green IT initiatives and was measured by two items to estimate the percentage of budget allocated for Green IT (Zhu and Kraemer, 2005). *Firm Size* was measured by the number of employees of the firm (Zhu et al., 2006b). *Regulatory Support* was measured by three self-developed items (also in accordance with Bose and Luo (2011)), to determine the role of legislations, regulations and incentives in Green IT adoption. *Competition Intensity* was measured by three items to determine the degree of competition that firm faces at local, national, and international markets (Zhu et al., 2006b).

4.2. DATA

Data was collected using an online survey over a two-month period (April-May 2012). 426 companies in Portugal were contacted and 251 completed responses were received. The respondents were qualified individuals (e.g., CEO, CFO, and business managers) to speak about the company's 'go green' process, which suggests a good quality of the data. The profile of the sample is shown in Table 4.1. The sample covered varying types of businesses and represented small (less than 50 employees) (34.7%), medium (between 50 and 250 employees) (41.4%), and large companies (more than 250 employees) (23.9%) in accordance to the European Commission standard for enterprise classification (Stenkula, 2006).

Table 4.1 - Sample Caracteristics

Sample Characteristics N=251	Obs.	(%)
Respondent title		
IS Managers	*42*	*16.7%*
IS Manager, Director, Planner	31	12.4%
Other Managers in IS Department	11	4.4%
Non-IS Managers	*209*	*83.3%*
CEO, President, Director	48	19.1%
Business Operations Manager, COO	21	8.4%
Administration/Finance Manager, CFO	50	19.9%
Quality Manager	23	9.2%
Others (Marketing, HR, Other Managers)	67	26.7%
No. Of Employees		
< 50	87	34.7%
50 – 250	104	41.4%
> 250	60	23.9%
Industry		
Manufacturing	64	25.5%
Wholesale and retail trade	40	15.9%
Construction	19	7.6%
Accommodation and food services activities	18	7.2%
Human health and social work activities	15	6.0%
Information and communication	14	5.6%
Public administration and defense	14	5.6%
Transportation and storage	13	5.2%
Professional, scientific, technical activities	13	5.2%
Others	41	16.2%

Note:
(1) The firm size is presented in accordance of European enterprises size class (Stenkula, 2006).
(2) The industries of activity are presented in accordance of NACE (European standard classification of productive economic activities).

To examine the existence of bias due to the position held by the respondents, we compared the sample distribution between IS managers and non-IS managers. The Kolmogorov-Smirnov (K-S) test was used to compare the sample distributions of the two groups. As shown in Table 4.2 the K-S test for each factor is non-significant at 1% ($p>0.01$), with the exception of firm size, which was found significant at 1% ($p<0.01$). Firm size is an objective characteristic of the organization that is not influenced by the opinion of the respondents. Hence we conclude that no significant bias exists between IS and non-IS managers. Furthermore, we examined the common method bias by using Harman's one-factor test (Podsakoff et al., 2003). The results found no significant common method bias in the data.

Table 4.2 – Testing possible Biases: IS Managers vs. Non-IS managers

	Full sample (n=251)		**IS managers (n=42)**		**Non-IS managers (n=209)**		**Kolmogorov-Smirnov test**	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Z score	P-value
Sensory Readiness	3.77	0.92	3.35	1.11	3.86	0.85	1.60	0.01
Relationship Readiness	3.58	0.96	3.48	1.02	3.61	0.95	0.41	1.00
Synchronism Readiness	3.38	0.74	3.00	0.65	3.46	0.74	1.43	0.03
Id & Control Readiness	3.33	0.86	3.21	0.88	3.35	0.85	0.44	0.99
Champion Support	4.19	0.66	4.24	0.84	4.18	0.63	0.47	0.98
Resource Commitment	11.60	20.16	9.60	20.29	12.00	20.15	0.86	0.46
Firm Size	374.95	1199.18	398.74	558.41	370.17	1291.05	1.73	0.00
Regulatory Support	3.66	0.60	3.67	0.61	3.65	0.60	0.32	1.00
Competition Intensity	3.06	0.76	3.11	0.74	3.05	0.76	0.69	0.74
Green IT Initialization	3.46	0.90	3.36	0.75	3.48	0.93	0.85	0.46
Green IT Integration	3.71	2.53	3.31	2.36	3.79	2.56	0.66	0.78
Green IT Maturation	15.07	20.47	11.62	19.35	15.77	20.67	0.86	0.45

5. RESULTS AND DISCUSSION

5.1. RESULTS

To examine the causal relationships of the conceptual model, Bose and Luo (2011) proposed the use of Structured Equation Modeling (SEM). We used Partial Least Square (SmartPLS 2.0.M3, Ringle et al. (2005)) to estimate the research model. Since this research is an early stage assessment and the theoretical model proposed by Bose and Luo (2011) has not been tested before, the use of PLS is suitable and adequate (Hair et al., 2012; Hair et al., 2011). Before testing the structural model, we examined the measurement model to assess reliability and validity.

5.1.1. Measurement model

The results of the measurement model are reported in Tables 5.1 and 5.2. We assessed construct reliability, indicator reliability, convergent validity, and discriminant validity. The construct reliability was tested using the composite reliability coefficient. PLS prioritizes indicators according to their individual reliability. Composite reliability is used instead of Cronbach's alpha to analyze the reliability of the constructs, since the former takes into consideration indicators that have different loading (Hair et al., 2012; Hair et al., 2011; Henseler et al., 2009; Werts et al., 1974) while Cronbach's alpha assumes that all indicators are equally reliable (Raykov, 2007). As shown on Table 5.1, all the constructs have a composite reliability above 0.7 which suggests that the constructs are reliable (Straub, 1989).

The indicator reliability was evaluated based on the criteria that the loadings should be greater than 0.70, and that every loading less than 0.4 should be eliminated (Churchill Jr, 1979; Henseler et al., 2009). As shown in Table 5.2, the loadings (in bold) are greater than 0.7, with the exception of two items (SYNC1 and REG3) which are lower than 0.7 but greater than 0.4. Hence no items in the table were eliminated. All the items are statistically significant at 0.001. Overall, the instrument presents good indicator reliability.

Average Variance Extracted (AVE) was used as the criterion to test convergent validity. The AVE should be higher than 0.5 so that latent variable explains more than half of the variance of it indicators (Fornell and Larcker, 1981; Hair et al., 2012; Henseler et al., 2009). As shown in Table 5.2, all constructs have an AVE higher than 0.5 fulfilling this criterion.

Discriminant validity of the constructs was assessed using two measures: Fornell-Larcker criteria and cross-loadings. The first criterion postulates that the square root of AVE should be greater than the correlations between the construct (Fornell and Larcker, 1981). The second criterion requires that the loading of each indicator should be greater than all cross-loadings (Chin, 1998a; Götz et al., 2010; Gregoire and Fisher, 2006). As seen in Table 5.1, the square roots of AVEs (diagonal elements) are higher than the correlation between each pair of constructs (off-diagonal elements). Table 5.2 shows that the patterns of loadings are greater than cross-loadings. Thus both measures are satisfied.

The assessment of construct reliability, indicator reliability, convergent validity and discriminant validity of the constructs are satisfactory, indicating that the constructs can be used to test the conceptual model.

Table 5.1 – Correlation matrix, Composite Reliability (CR) and square root of AVEs

Constructs	CR	SENS	REL	SYNC	IC	CHAMP	RES	SIZ	REG	COMP	INI	INTEG	MAT
Sensory Readiness	**0.85**	**0.86**											
Relationship Readiness	**0.91**	0.40***	**0.92**										
Synchronism Readiness	**0.71**	0.29***	0.39***	**0.75**									
Id & Control Readiness	**0.80**	0.22***	0.19***	0.15**	**0.82**								
Champion Support	**0.92**	0.12	0.10	0.06	0.10	**0.89**							
Resource Commitment	**0.96**	0.13**	0.07	0.08	0.02	-0.12	**0.96**						
Firm Size	**n.a**	-0.02	-0.08	-0.06	-0.08	0.12	-0.07	**n.a**					
Regulatory Support	**0.75**	0.06	0.10	0.09	0.05	0.31***	-0.03	0.04	**0.71**				
Competition Intensity	**0.91**	0.07	0.06	0.13**	0.07	0.12	0.19***	0.14**	0.23***	**0.88**			
Green IT Intialization	**0.90**	0.15**	0.06	0.18***	0.12	0.17***	0.14**	-0.05	0.37***	0.42***	**0.84**		
Green IT Integration	**n.a**	0.04	-0.01	-0.01	-0.01	0.09	0.17***	0.03	0.15**	0.25***	0.35***	**n.a**	
Green IT Maturation	**0.90**	0.05	-0.01	-0.05	-0.05	0.03	0.33***	-0.03	0.05	0.25***	0.28***	0.52***	**0.86**

Notes:
(1) n.a. Composite Reliability and Average Variance Extracted are not applicable to the single-item constructs.
(2) First column are CR (Composite Reliability).
(3) Diagonal elements are square Average Variance Extracted (AVE).
(4) Off-diagonal elements are correlations
(5) * significant at the 0.1; ** significant at the 0.05; *** significant at the 0.01

Table 5.2 - Loadings and cross-loadings for the measurement model

Construct	Item	SENS	REL	SYNC	IC	CHAMP	RES	SIZ	REG	COMP	INIT	INTEG	MAT
Sensory Readiness	SENS1	**0.98**	0.35	0.28	0.21	0.12	0.13	0.00	0.09	0.08	0.17	0.07	0.05
	SENS2	**0.72**	0.42	0.23	0.17	0.06	0.07	-0.08	-0.04	0.02	0.05	-0.06	0.05
Relationship Readiness	REL1	0.42	**0.89**	0.39	0.14	0.09	0.05	-0.11	0.08	0.04	0.05	-0.03	-0.02
	REL2	0.32	**0.94**	0.32	0.20	0.09	0.08	-0.04	0.10	0.06	0.06	0.00	0.00
Synchronism Readiness	SYNC1	0.23	0.28	**0.58**	0.07	0.03	0.15	-0.10	0.03	0.18	0.10	-0.05	0.02
	SYNC2	0.22	0.31	**0.88**	0.14	0.06	0.00	-0.01	0.09	0.05	0.17	0.02	-0.07
Identification & Control Readiness	IC1	0.22	0.21	0.19	**0.91**	0.15	0.06	-0.08	0.05	0.07	0.11	-0.02	-0.06
	IC2	0.12	0.07	0.01	**0.71**	-0.04	-0.06	-0.04	0.02	0.04	0.07	0.00	0.00
Champion Support	CHAMP1	0.05	-0.01	0.06	0.01	**0.84**	-0.19	0.12	0.22	0.11	0.13	0.06	-0.04
	CHAMP2	0.14	0.15	0.06	0.14	**0.93**	-0.06	0.05	0.32	0.12	0.19	0.11	0.07
	CHAMP3	0.10	0.08	0.04	0.08	**0.89**	-0.09	0.19	0.26	0.08	0.10	0.07	0.05
Resource Commitment	RES1	0.13	0.07	0.08	0.03	-0.09	**0.98**	-0.07	-0.02	0.23	0.16	0.19	0.34
	RES2	0.12	0.07	0.07	0.01	-0.16	**0.95**	-0.06	-0.05	0.11	0.09	0.13	0.29
Firm Size	SIZE	-0.02	-0.08	-0.06	-0.08	0.12	-0.07	**1.00**	0.04	0.14	-0.05	0.03	-0.03
Regulatory Support	REG1	0.02	0.04	0.00	0.09	0.36	-0.06	0.10	**0.77**	0.19	0.23	0.12	0.00
	REG2	-0.02	0.00	-0.04	-0.04	0.38	-0.03	0.09	**0.71**	0.18	0.24	0.14	0.11
	REG3	0.12	0.15	0.19	0.05	-0.03	0.02	-0.08	**0.65**	0.13	0.30	0.06	0.00
Competition Intensity	COMP1	0.10	0.05	0.14	0.13	0.10	0.13	0.13	0.20	**0.88**	0.40	0.20	0.18
	COMP2	0.09	0.09	0.12	0.11	0.10	0.23	0.11	0.19	**0.91**	0.33	0.20	0.21
	COMP3	0.00	0.02	0.08	-0.07	0.12	0.16	0.13	0.22	**0.84**	0.38	0.25	0.27
Green IT Initialization	INIT1	0.01	-0.07	0.10	0.04	0.20	0.06	-0.02	0.30	0.38	**0.76**	0.32	0.25
	INIT2	0.19	0.08	0.17	0.13	0.05	0.12	-0.09	0.31	0.35	**0.87**	0.27	0.21
	INIT3	0.16	0.09	0.17	0.11	0.04	0.14	0.04	0.30	0.35	**0.85**	0.26	0.22
	INIT4	0.15	0.10	0.18	0.11	0.25	0.14	-0.10	0.33	0.35	**0.87**	0.33	0.26
Green IT Integration	INTEG	0.04	-0.01	-0.01	-0.01	0.09	0.17	0.03	0.15	0.25	0.35	**1.00**	0.52
Green IT Maturation	MAT1	0.09	0.00	0.02	-0.05	0.01	0.33	-0.06	-0.01	0.21	0.27	0.44	**0.88**
	MAT2	0.06	0.02	-0.07	0.02	0.06	0.27	-0.05	0.05	0.26	0.24	0.46	**0.90**
	MAT3	-0.01	-0.04	-0.06	-0.09	0.02	0.26	0.03	0.08	0.16	0.21	0.44	**0.80**

5.1.2. Structural model

The structural model was assessed using R^2 measures and the level of significance of the path coefficients. Figure 5.1 shows the model results. The R^2 of dependent variables are respectively 0.33, 0.16 and 0.30 for Green IT Initialization, Green IT Integration and Green IT Maturation. The significance of the path coefficients was assessed by means of a bootstrapping procedure (Hair et al., 2011; Henseler et al., 2009) with 500 times resampling (Chin, 1998b). Figure 5.1 also shows the path coefficients and t-value results.

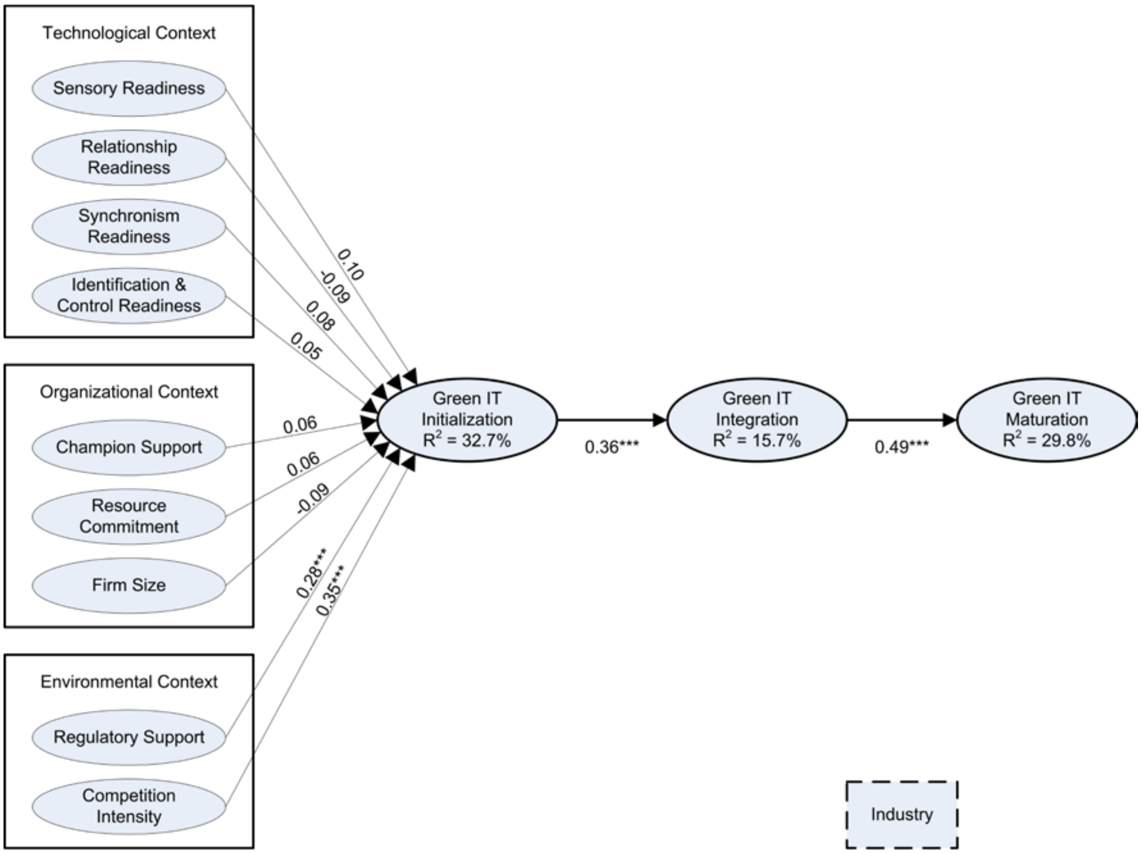

Figure 5.1 – Model with results

Within the technological context, the study found that sensory readiness ($\hat{\beta}$ =0.10; p>0.10), relationship readiness ($\hat{\beta}$ =-0.09; p>0.10), synchronism readiness ($\hat{\beta}$ =0.08; p>0.10), and identification and control and control readiness ($\hat{\beta}$ =0.05; p>0.10) are not statically significant. Thus, hypothesis H1, H2, H3 and H4 are not confirmed.

Within the organizational context, it is seen that champion support ($\hat{\beta}$ =0.06; p>0.10), resource commitment ($\hat{\beta}$ =0.06; p>0.10) and firm size ($\hat{\beta}$ =-0.09; p>0.10) are not statistically significant to explain Green IT Initialization. Thus, hypothesis H5, H6 and H7 are not confirmed.

Within the environmental context, the results show that regulatory support ($\hat{\beta}$ =0.28; p<0.01) has significant and positive path to Green IT Initialization. Moreover, competition intensity ($\hat{\beta}$ =0.35; p<0.01) also has a significant (p<0.01) and positive path to Green IT Initialization. Thus, the two hypotheses (H8 and H9) for the environmental context are supported.

With regard to the adoption stages, it is found that the pre-adoption stage (i.e. Green IT Initialization) has a statistically significant ($\hat{\beta}$ =0.36; p<0.01) and positive path to explain Green IT Integration (i.e., formal adoption stage). The formal adoption stage has statistically significant ($\hat{\beta}$ =0.49; p<0.01) and positive path to explain Green IT Maturation (i.e., post-adoption stage).

5.2. Discussion

5.2.1. Major findings

The objective of this study was to identify the factors that influence the adoption of Green IT practices through virtualization. An integrative research model was proposed that links organizational adoption and implementation of Green IT via virtualization to the technological, organizational, and environmental factors. The study shows that environmental context is more significant to the adoption of Green IT initiatives than technological and organizational context. An explanation for the diminished significance of the technological and organizational context may be that the benefits of green IT are well recognized by organizations and virtualization initiatives are already underway in the firms. Additionally sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness is not a serious concern among IS and non-IS managers as demonstrated in our model. The findings offer instrumental insights for practitioners and researchers. We summarize them below.

5.2.2. Practical implications

The study suggests the important role of environmental context in Green IT adoption compared to technological and organizational factors. The findings indicate that competitive intensity and regulatory support plays a key role in the firm's adoption of Green IT initiatives. A plausible explanation for the organizational response to competitive intensity may be the role of external forces such as mimetic pressures, social responsibility, and compliance requirements. The strategic directive to create an image identity from sustainability initiatives may also provide the impetus to pursue Green IT initiatives. The competitive advantage from initiating Green IT schemes, cost saving from process virtualization, and the brand recognition generated from going 'Green' can prioritize the organization's adoption of Green IT.

Regulatory support emerging as an important factor for adoption of Green IT is relevant to policy makers. Supportive government legislations and policies can coarse the adoption of green practices by organizations. Thus, policy makers can play a role in enabling organizations to implement environmental sustainability in their business and IT practices. The findings make a sound argument for elevated roles of supportive government actions (for e.g., offering incentives, technical support, tax relief, funding, etc.) on the potential for organizations to implement Green IT initiatives.

Furthermore, the findings confirm the link between the adoption stages of Green IT. The formal stage of adoption (i.e., Green IT integration) is influenced by the pre-stage of adoption (i.e., Green IT initialization) and the post-adoption stage (i.e., Green IT maturation) by the formal stage of adoption (i.e., Green IT integration).

5.2.3. Theoretical contributions

This research presents important contributions to the IS community. First, it empirically tests the conceptual model proposed by Bose and Luo (2011) to assess the firm's readiness to go green via virtualization. Second, the research developed a survey instrument with items related to process virtualization that mirror the contextual attributes of Green IT (Bose and Luo, 2011; Overby et al., 2010). The instrument was tested for reliability and validity of the scales, and used successfully to collect data from 251 companies in Portugal. Future researchers can readily use the instrument to replicate the study across industries in other countries.

The study contributes to a better understanding of Green IT adoption via virtualization while adding new knowledge to this emergent areas of IS research. Unlike most of the studies in the literature of innovation diffusion that use an "adoption versus non adoption" approach, we test the link between the three adoption stages.

6. CONCLUSIONS

As consumer preferences become greener, and companies are tasked to become socially responsible through sustainable products and practices, Green IT has emerged as a prime research topic. To assess an organization’s potential to undertake Green IT initiatives via virtualization, Bose and Luo (2011) proposed an integrative model based on three popular IS theories: Technology-Organization-Environment (TOE) framework, Process Virtualization Theory (PVT), and Diffusion of Innovation (DOI) theory. This study empirically evaluated the conceptual model using data collected from Portugal. Environmental context (regulatory support and competition intensity) is found more meaningful in explaining the adoption of Green IT than technological and organizational context. The adoption stages of Green IT are also evaluated. Using the model, we validate that the pre-adoption stage (i.e., Green IT initialization) influences the formal stage of adoption (i.e., Green IT integration), which in turn influences the post-adoption stage (i.e. Green IT maturation).

7. LIMITATIONS AND FUTURE RESEARCH

As with any empirical studies, our study has some limitations. First, we used cross-sectional data, which does not allow us to observe the evolution of a firm's Green IT adoption via virtualization. The diffusion of a technology in an organization is a complex process that takes time to incorporate and mature. To address this limitation, a longitudinal study could be more appropriate to analyze the different stages of adoption of Green IT. Second, this study was carried out in Portugal. It will be interesting to determine whether the findings may differ in others countries in accordance with their technological advancements and regulatory push towards Green IT adoption. To address this limitation, we encourage future researchers to apply the model and adapt the instrument for use in others countries. Third, our focus was not on any particular sector. Some industries (for e.g., the service sector) are more technologically advanced than others (for e.g., agriculture), and the results could be different. To address this limitation, we encourage additional research to test the model in different target industries. Forth, this model only analyzes the relationship between the three adoption stages. Thus, we encourage additional research focused on the effects of TOE and PVT factors on all stages of the diffusion process. Finally, the study determined that the environmental context plays a critical role in Green IT initiatives. Further research to confirm why the environmental context and regulatory support are crucial can be beneficial to policy makers to develop policies that will promote business to adopt other sustainability initiatives in addition to Green IT.

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9. APPENDIX – SURVEY QUESTIONNAIRE

A. *Adoption Stages*

Green IT Initiation. Please indicate how significant each of the following potential benefits of Green IT via virtualization was rated when your organization was considering to use these technologies (On a scale 1 – 5 , 1 is Not Important and 5 is Very Important.).

INIT1. Increased Productivity.

INIT2. To expand market for existing products/services.

INIT3. To enter new businesses or markets.

INIT4. To improve coordination with customers and suppliers.

Green IT Integration. Check the box describing applications of Green IT via virtualization in your value chain processes (check as many as apply):

INIT1. Advertising and marketing. (Y/N)

INIT2. Making sales online. (Y/N)

INIT3. After-sales support. (Y/N)

INIT4. Customer management. (Y/N)

INIT5. Exchanging operational data with suppliers. (Y/N)

INIT6. Making purchases online. (Y/N)

INIT7. Exchanging operational data with business partners and customers. (Y/N)

INIT8. Integrating business processes with business partners (e.g., real-time transaction of orders, integrated channel management, etc.) (Y/N)

Green IT Maturation. Please indicate the percentage of usage of virtualization to support your company value chain activities:

MAT1. What percent of your total sales B2C/B2B is conducted through Green IT initiatives? #

MAT2. What percent of your total services B2C/B2B is conducted through Green IT initiatives? #

MAT3. What percent of procurement (supplies and equipment) is conducted through Green IT initiatives? #

B. *Technologic context*

Sensory Readiness. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

SENS1. I like to touch / see / hear / smell the products.

SENS2. It's important physically inspect the products before purchase them.

Relationship Readiness. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

REL1. I like to have a personal relationship with the seller when I buy a product/service.

REL2. I consider my relationship with the seller when I purchase a product/service.

Synchronism Readiness. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

SYNC1. After I purchase a product, I need to get it that day or the next.

SYNC2. I like to take care of all purchasing-related activities in the day that I make an order.

Identification and Control Readiness. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

IC1. It is possible that people can hide their identity in virtual process.

IC2. Participants in virtualization process can be properly identified.*

C. Organizational Context

Champion Support. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

CHAMP1. The implementation or acceptance of Green IT initiatives requires support from the organization's top management.

CHAMP2. Champion support can help overcome possible resistance in adoption new technologies.

CHAMP3. Support of a champion is a significant factor in successful adoption and implementation of a Green IT strategy.

Resource Commitment. Please indicate the percentage destined for:

RES1. Green IT operating budget, as percent of total revenue. #

RES2. Green IT spending, as percent of total revenue. #

Firm Size

SIZ1. How many employees does your organization have in total? #

D. Environmental Context

Regulatory Support. Please rate the degree to which you agree with the following statements (On a scale 1 – 5, 1 is Strongly Disagree and 5 is Strongly Agree).

REG1. Regulatory support (legislation and regulation) can aid organizations to adopt Green IT.

REG2. Incentives for greening IT (technical support, tax relief, funding, etc) can aid organizations to adopt Green IT.

REG3. There is legislation that protects companies to adopt technologies such as virtualization.

Competition Intensity. Please rate the degree to which your business activities are affected by competitors (On a scale 1 – 5, 1 is Not Affected and 5 is Strongly Affected).

COMP1. in the local market.

COMP2. in the national market.

COMP3. in the international market.

Notes:

(1) #, continuous variable; Y/N, dummy variable; 1 – 5, 5-point Likert scale.

(2) Items with an * are reverse scales.